

A LONG-TERM SPACE ASTROPHYSICS RESEARCH PROGRAM
AN X-RAY PERSPECTIVE OF THE COMPONENTS AND STRUCTURE
OF GALAXIES

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ASTROPHYSICS RESEARCH PROGRAM: AN X
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Semiannual Report No. 4

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1 Activities at SAO

A paper describing the ROSAT PSPC observations of NGC 4636 is almost completed. We find a temperature gradient in the hot ISM, and a halo extending way past the optical galaxy. A ROSAT proposal to investigate this halo, and hopefully to discriminate between a galaxy component and the hot Virgo ICM has been accepted with priority C.

We have also analyzed the ROSAT observations of two X-ray faint ellipticals. We confirm the results based on the Einstein data that these galaxies have two emission components: a hard component, and a supersoft component. A paper reporting the results of this data analysis has been circulated internally at CfA and will be submitted to Ap. J. shortly. In collaboration with Silvia Pellegrini of ESO, we have compared these data to the results of hydrodynamical models, to explore the possibility that the supersoft component may be due to a warm ISM. A paper describing this work is in the latest stages of revision. A ROSAT proposal to extend these studies has been approved with priority B.

A proposal was submitted together with MIT and Japanese collaborators to explore the Lx/LB plane of elliptical galaxies with ASCA.

We are completing the analysis of our HST observations of cores of early-type galaxies. We find centrally rising surface brightness profiles and UV-bright point sources in two case, suggesting the possibility of a central black hole. In another galaxy, we have discovered an arcsec-size dust lane. We plan to report the results in three papers. The first one has already been circulated internally for comments and will be submitted to Ap. J. soon. The second is in draft form. A proposal for a follow-up HST program has been submitted.

Work is also nearing completion in our statistical analysis of the Einstein early-type galaxy sample. We find differences in the X-ray luminosity distributions of E and S0, and other connections with structural parameters.

As part of our Ginga collaboration, we have supported the visit to SAO of a graduate student of the university of Tokyo. A paper reporting the Ginga observation of 3C390.3 (Inda et al 1993) has been submitted to Ap.J.

Glen Mackie, the scientist supported by this grant, is setting up a pipeline to analyze archival ROSAT data. We plan to obtain all the pointed data as soon as they are released to the public and to extract all the data relevant to normal galaxies, using optical catalogs as a guide. The results of this systematic analysis will be a catalog of X-ray data on galaxies, that will extend the Einstein catalogs published on the Ap. J. Supp. (Fabbiano, Kim, and Trinchieri 1992; Kim, Fabbiano and Trinchieri 1992).

1.1 Papers:

X-ray Properties of Early-type Galaxies (G. Fabbiano), ESO proc. of the Elba Conference (J. Danziger, W. W. Zeilinger and K. Kjar, eds.), ESO proc. No. 45, p. 617.

X-ray Properties of Normal Galaxies (G. Fabbiano), Proc. of the COSPAR Symp. held in Washington DC (J. Truemper, ed.)

Analysis of the Einstein sample of early-type galaxies (P. B. Eskridge and G. Fabbiano), proc. of the Teton's meeting on galaxies.

Coronal Stellar Emission in Galaxies (G. Fabbiano), to be published in Advances in Stellar and Solar Coronal Physics (J. F. Linsky and S. Serio, eds; Kluwer).

- Normal Galaxies and their X-ray Binary Populations (G. Fabbiano), to appear in "X-ray Binaries" (W. Lewin, J. van Paradijs, and E. van den Heuvel, eds; Cambridge Univ. Press).
- X-ray Continuum and Iron K Emission Line from the Radio Galaxy 3C390.3 (M. Inda, K. Makishima, Y. Kohmura, M. Tashiro, T. Ohashi, P. Barr, K. Hayashida, G. G. C. Palumbo, G. Trinchieri, M. Elvis, and G. Fabbiano), Ap. J. submitted.
- High Resolution Optical and UV Observations of the Centers of NGC 1316 and NGC 3998 (G. Fabbiano, C. Fassnacht, and G. Trinchieri), preprint.
- ROSAT PSPC observations of two X-ray faint early-type galaxies: NGC 4365 and NGC 4382 (G. Fabbiano, D.-W. Kim, G. Trinchieri, and C. R. Canizares), preprint.

1.2 Recent Talks by G. Fabbiano:

- Space Observations of Early-type Galaxies; MIT astrophysics colloquium – 6 april 1993
- Space Observations of Early-type Galaxies; invited talk at the Accademia dei Lincei (Rome, Italy)– may 1993
- X-ray observations and cooling flows in elliptical galaxies; review talk at the Aspen workshop on galaxy halos – june 1993
- X-ray observations of galaxy halos; review talk to be given at the HST workshop on galaxy halos – aug 1993

2 Activities at MIT

The paper "Insignificance of Heating Flows in Cooling Flow Clusters" was revised, accepted and has appeared in press (Canizares et al. 1993). In collaboration with Andrew Fabian and Hans Bohringer we evaluated a "steady state" evaporation model proposed by W. Sparks (1992 ApJ, 399, 66) to explain cluster cooling flows and found several significant difficulties with its assumptions and conclusions. We find the model is untenable since it requires planar geometry to explain the observed X-ray spectra of cooling flows but it then in conflict with the observed X-ray images; the model also has implausible boundary conditions. Moreover, the supposed evaporating region was itself embedded in a cooling flow. Finally, the solution, which is assumed static, is highly unstable. A paper detailing these conclusions, "Mergers, Cooling Flows and Evaporation Revisited" by Fabian, Canizares and Bohringer has been submitted to ApJ.

We are completing analysis of ROSAT data on the elliptical galaxy NGC720. We find that the X-ray isophotes are elliptical at radii of $\sim 200''$ with position angle offset by ~ 15 degrees from that of the optical galaxy. Detailed modeling of the gravitational potential of prolate and oblate ellipsoids shows that matter distributed like the stars cannot explain the observed X-ray isophotes regardless of its mass. Composite models, with a galaxy plus an ellipsoidal dark halo, show that a massive extended halo is required – the halo must contain at least ~ 10 times the stellar mass within ~ 300 arc seconds. We obtain a well constrained temperature for the gas of ~ 0.6 keV. If we assume isothermality, the implied mass of the halo is $\sim 10^{12}$ solar masses. We are now completing our modeling and a paper reporting these results is in preparation. We have proposed a ROSAT HRI observation of NGC720 in

hopes of improving our models in the interior regions, where the PSPC point spread function dominates.

We have similar data for an even flatter E/S0 galaxy, NGC 1332. However, the source is slightly off axis, which complicates the point spread function. We intend now to pursue that source with a similar analysis.

We also plan to continue our studies of the shapes of clusters of galaxies. As in the case of NGC720, we plan to apply multi-component models that include both galaxies and dark matter. We also need to test the sensitivity of our conclusions to possible subclustering and to departures from full relaxation of the cluster. We have also intend to use ROSAT data to improve our determination of the shapes of the X-ray isophotes. Some of this data is now becoming available through the ROSAT archive. In the case of Coma, we are collaborating with Simon White and Kimberly Dow, who have been analyzing four well-exposed fields that cover much of the cluster.

One of us (CRC) is collaborating with Andrew Fabian in writing a review on cooling flows in clusters for Annual Reviews of Astronomy and Astrophysics.

We supported the analysis of ROSAT PSPC data on NGC4636, being lead by G. Trinchieri. Specifically, we considered how the deduced electron densities of the emitting gas would be affected if the material had two phases at different temperatures. We also reviewed the manuscript, which is now under revision.

A plan for initial observations of galaxies to be performed by the ASCA (Astro-D) satellite was formulated as part of the PV-phase planning process. This was done together with other members of the ASCA team. Following the successful launch last month, data on these objects should begin arriving over the next several months.

2.1 Papers:

Buote, D. and Canizares, C. R. "X-ray Constraints on the Shape of the Dark Matter in Five Abell Clusters" 1992 ApJ 400, 385.

Canizares, C.R., Markert, T.H., Markoff, S, and Hughes, J.P. Hughes, "The Insignificance of "Heating Flow" in "Cooling Flow" Clusters of Galaxies, 1993 ApJ (Letters) 405, L17.

Fabian, A.C. Canizares, C.R. and Bohringer H. "Mergers, Cooling Flows and Evaporation Revisited" 1993 ApJ (submitted).

2.2 CRC Talk:

The Shape of the Dark Matter in Clusters and Galaxies, Institute of Astronomy, University of Cambridge, March 1993. (invited)